City of Indianapolis
Department of Public Works
Raw Sewage Overflow Control Program

Cost Estimating Procedures for Raw Sewage Overflow Control Program

INDIANAPOLIS
CLEAN STREAM TEAM

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1.0 Introduction

This document presents procedures for developing project cost estimates for various long-term raw sewage overflow control alternatives. These procedures will be applied to develop conceptual planning cost estimates that will provide a basis for comparing different technologies and characterize the potential economic impact in relation to other control alternatives.

The cost estimating procedures in this document are a guideline and reference for screening raw sewage overflow control alternatives, in preparation of the long-tern control plan (LTCP) for the city's Raw Sewage Overflow Control Program. The level of detail in this document is consistent with the objective: to support concept-level cost estimates for screening alternative control approaches. It does not present procedures for detailed cost analysis (such as would be used for facilities planning-type cost estimates), as this would impede, rather than support, conceptual planning. The approach includes a thorough evaluation of facility requirements and cost estimates with sufficient detail to support sound decisions on the direction of the long-term planning.

This document presents the unit costs for the construction and operation and maintenance (O&M) of various raw sewage overflow control technologies and procedures. These costs can be used to develop total capital costs and total present worth costs.

This document consists of this introduction and the following five sections:

- Section 2, General Project Costs and Cost Assumptions -- Presents the list of references used, along with general assumptions for developing capital and O&M costs. This section presents the basis for developing present worth and equivalent annual costs; it also presents the economic service life for major raw sewage overflow control components. In addition, it describes how multiple-function facilities and ancillary facilities are handled in developing cost estimates.
- Section 3, Minimum Technology Control Facilities -- Provides the cost estimating procedures for in-system storage facilities such as inflatable dams, automated sluice gates, and end-of-pipe treatment devices including netting devices and overflow screens.
- Section 4, Conveyance Facilities -- Presents cost curves for new sewer construction and pump station facilities. In addition, this section provides cost estimating procedures for total sewer separation projects.
- Section 5, Treatment Facilities -- Provides cost estimating procedures for various treatment alternatives such as mechanical screens, chlorination and dechlorination, ultraviolet disinfection, and enhanced high rate clarification.
- Section 6, Storage Facilities -- Presents procedures for estimating the costs of storage facilities, including earthen, prestressed concrete and concrete storage facilities, as well as deep tunnel storage.

2.0 General Project Costs And Assumptions

This section presents the references used to develop project costs and the methodology for developing the cost equations and unit costs.

2.1 References

The cost data were developed based on information from the following references.

- Combined Sewer Overflow Control, U.S. Environmental Protection Agency (U.S. EPA); July 1994
- Costs for Select CSO Control Technologies, U.S. EPA; October 1992
- CSO Guidance for Long-term Control Plan, U.S. EPA; September 1995
- Approaches to CSO Program Development, AMSA; November, 1994
- CSO Control Manual, U.S. EPA; September 1993
- CSO Needs Survey, U.S. EPA; 1992
- Control and Treatment of CSOs, edited by Peter E. Moffa, Published by Van Nostrand Reinhold; 1990
- Means Construction Cost Data; 2003
- Innovative and Alternative Technology Assessment Manual; 1980

2.2 Methodology

The U.S. EPA references were the most current and comprehensive sources of costs for raw sewage overflow control technologies and were therefore the primary source for obtaining construction costs. The other references yielded cost data that were not available in the U.S. EPA references; they also enabled comparison with the U.S. EPA data.

The following methodology was used for developing the cost equations and unit costs. The intent was to maintain the integrity of the original U.S. EPA cost equations when available, yet adjust the equations to local conditions.

- The U.S. EPA cost equations provide the cost basis for the majority of control technologies. When U.S. EPA data were not available or too general, equations were developed from actual cost data and regional experience. The equations were adjusted for current local conditions with the *Engineering News Record* Construction Cost Index (ENRCCI). Because the *Engineering News Record* cost index criterion does not include Indianapolis, the index for Cincinnati, Ohio (the nearest comparable city) was used. The cost equations and unit costs are based on an ENRCCI of 6635 (April 2003). The equations provide the base construction cost.
- Site adjustment factors to account for unique characteristics not covered by the equations were used as appropriate. For example, dewatering, rock excavation, and land acquisition are covered in this way. The factors are multiplied by the cost equations to provide the adjusted base construction cost.
- Total Construction cost includes the results from the adjusted base construction cost plus the site adjustments and a contingency factor of 25 percent.
- Land cost includes cost of land required for right-of-way or easements for the construction, operation and maintenance of the proposed control technologies.
- Engineering, administration and inspection costs consist of 25 percent of total construction costs plus land costs.

- Project (Capital) cost is the sum of total construction costs; land costs; and engineering, administration and inspection costs.

Facility costs are highly variable per given process due to site specificity such as location, depth, support facilities and ease of construction. Based on the level of project development and the variability inherent in the cost sources, these equations represent an accuracy of ± 30 to 50 percent. These cost equations and unit costs are expected to be appropriate for comparing prospective alternatives. As the project evolves, construction cost estimates will continually be refined to better represent actual conditions.

2.3 Total Construction Costs

The total program costs cover all costs as currently envisioned for project construction. These costs include base construction costs; site adjustment factors such as appurtenances, utility conflicts, dewatering, traffic routing, pavement restoration, excess materials disposal, and construction contingency. Total construction costs can be represented by the following formula:

*Total Construction Costs ($) = (BCC * (ENRCCI/6635) * 1.SAF) * C*

Where:

BCC	=	Base construction cost per U.S. EPA equation
ENRCCI	=	*Engineering News Record* construction cost indices at the time of estimate
SAF	=	Site adjustment factors (see Table 1)
C	=	Contingency for undeveloped design (minimum 1.25)

2.3.1 Site Adjustment Factors

Costs related to site adjustment factors (SAF) are estimated based on the total percentages for specific site conditions as shown on Table 1 times the base construction cost.

Table 1
Site Adjustment Factors

Project Feature	Guidance
Manholes and appurtenances	• 2% large diameter to 10% for less than 18 inch, • 0 % for tunnels
Utility conflicts	• 5% urban • 2% suburban • 0% rural
Dewatering	• 1% – 3% (additional required for areas parallel to major water bodies) • 0 % for tunnels
Traffic routing	0% - 1% based on location 0.5 % for tunnels
Pavement restoration	• 15% urban • 5-10% suburban • 0-1% rural • 0% for tunnels, use GIS impervious as guidance
Excess materials disposal	• 1% - 5% for sewer projects

Project Feature	Guidance
	• 0% for tunneling - use soils quality and impervious as guidance
Additional adjustment required at engineer's adjustment	Rock excavation, hazardous materials (requires written explanation of content and purpose; see text for potential examples)

2.3.2 Other Construction Cost Considerations

Other issues, which may affect project costs, include facility siting costs, treatment plant capacity issues, and non-economic issues. These site-specific issues should be evaluated in terms of their perceived impact on the cost effectiveness of each alternative. The methodology should include evaluation of deep versus shallow sewers where applicable.

2.3.3 Multiple-Function and Ancillary Facilities

Raw sewage overflow control alternatives often include multiple functions for a control facility, and these functions must be reflected in the cost. For example, if a storage basin is also considered for treatment, then the estimated costs need to consider the additional cost of treatment components. Other examples include the following:

- The storage costs do not include pumping. Add the costs from storage alone to the costs required for pumping facilities.
- The storage costs do not include disinfection. Add disinfection costs as needed.
- Pumping costs do not include force main. Add pipeline costs as required.
- Enhanced treatment includes only high rate separation. Include screening and disinfection as required.
- Chlorine disinfection does not include chlorine contact chamber. Include cast in place storage where needed for contact basin.

2.4 Land Costs

Land required for right-of-way or easements; for the construction, operation and maintenance of the proposed control technologies; is estimated on a project-specific basis. Land costs are estimated based on the unit cost per acre, using prevailing market rate. Where land required for the facility is not specifically identified; the land costs are estimated based on a percentage of base construction cost, for a specific type facility, as shown on Table 2.

Table 2

Land Costs

Project Feature	Guidance
Land Costs (for Right-of-way or easements)	• If estimated acreage is available, use $__ per acre • 5% average • 0.5% to 1% for tunnels • 3% to 5% for open cut large diameter sewers • 0% to 1% for treatment plant construction • 2% to 3% for surface storage

2.5 Engineering, Administration and Inspection Costs (Non-Construction Costs)

Engineering, administration and inspection (EAI) includes engineering fees for facilities planning, design, inspection, construction management costs, administration costs for project management, funding reporting requirements, public relations efforts, contract management and associated legal support costs. This has been historically estimated at an average of 25 percent of the project construction cost and is variable based on the magnitude, duration, complexity and uniqueness of the project.

*EAI Costs ($) = (Total Construction Costs ($) + Land Costs ($)) * EAI Factor (0.25)*

Where:

EAI = Engineering, administration, inspection factor (minimum 0.25)

2.6 Project (Capital) Costs

The project (capital) costs cover all costs for a project as currently envisioned. Project costs can be represented by the following formula:

Project (Capital) Costs ($) = Total Construction Costs ($) + Land Costs ($) + EAI Costs ($)

2.7 O&M Costs

O&M costs, in general, include energy consumption, labor requirements, residual disposal, and equipment maintenance. O&M costs for raw sewage overflow control facilities are presented whenever reliable data are available from the listed references. These costs are highly site-specific and very difficult to predict due to the intermittent nature of raw sewage overflows.

O&M costs are a function of overflow frequency and facility activation, design capacity, and the components included in the facility. Therefore, evaluation of raw sewage overflow control alternatives should include a detailed analysis of O&M costs based on the technology being evaluated and on site-specific conditions. Due to the site specific nature of the O&M requirements, the costs presented in this document are expected to provide an estimate of the cost to operate and maintain the raw sewage overflow control facilities.

2.8 Service Life

Table 3 presents the service life for major raw sewage overflow control components. These figures are based on the U.S. EPA cost-effectiveness guidelines.

Table 3
Service Life

Component Type	Service Life
Land	Permanent
Wastewater conveyance structure (including collection systems, outfall pipes, interceptors, force mains, drop shafts, tunnels)	50 years
Other structures (Including plant buildings, concrete process tankage, basins, lift station structures, and site work)	40 years
Process equipment (including major process equipment such as clarifier mechanisms, vacuum filters, etc.; steel process tanks and chemical storage facilities; electrical generating facilities on standby service only)	20 years
Auxiliary equipment (including instruments and control facilities; sewage pumps and electrical motors; mechanical equipment such as compressors, aeration systems, centrifuges, chlorinators; electrical generating facilities on regular service)	10 years

2.9 Replacement Costs

The future replacement costs for all facility components having service life of less than 20 years (e.g. auxiliary equipment having service life of 10 years) are estimated based on total capital costs required at the end of each component's service life.

2.10 Salvage Values

The salvage values (residual values) are determined for all facility components having service life of greater than 20 years (e.g. tunnels having service life of 50 years). The salvage values are estimated from the service life of each component, using straight line depreciation.

2.11 Present Worth and Equivalent Uniform Annual Costs

"Present Worth" may be thought of as the sum which, if invested now at a given rate, would provide exactly the funds required to make all future payments. "Equivalent Uniform Annual Cost" is the expression of a nonuniform series of expenditures as a uniform annual amount. Either of these methods may be used in the economic evaluation of alternatives.

To permit economic analysis and evaluation of alternative wastewater management systems, all cost estimates must be presented in a common dollar base. For the city's LTCP, all costs will be updated and expressed in terms of 2004 dollars and the cost-effectiveness analysis will be performed on a present worth basis. Each project alternative shall be evaluated using a 20-year planning period, recognizing the service life of facility components and including replacement costs within 20-year planning period and salvage value of components with service life beyond the 20-year horizon. To calculate present worth, the annual interest rate used shall be equivalent to either the current rate or present mandated rate used by the U.S. EPA for federal projects. The present worth analysis should include all front end capital costs, annual O&M costs, service life (replacement) costs, and salvage value (if applicable). Inflation is not considered during the 20-year planning period, unless specifically stated.

Present worth of annual O&M costs will be equal to annual O&M costs times the uniform series present worth factor at the prescribed interest rate for 20 years.

Present worth of the future replacement costs which occur at year 10 will be equal to future replacement costs times the single payment present worth factor at the prescribed interest rate for 10 years.

Present worth of salvage values at the end of 20 years will be equal to salvage values times single payment present worth factor at the prescribed interest rate for 20 years.

To find equivalent uniform annual cost, multiply the estimated present worth costs times the capital recovery factor at the prescribed interest rate for 20 years.

3.0 Minimum Technology Control Facilities

Two types of minimum technology structural control facilities are considered for the Raw Sewage Overflow Control Program: in-line storage facilities and end-of-pipe treatment devices. This section briefly describes these facilities and provides estimated construction costs.

3.1 In-System Storage Facilities

In-system storage facilities are used to maximize the in-system storage potential in the existing collection system during storm events to temporarily store wet-weather flow. Two types of facilities are considered for the Raw Sewage Overflow Control Program: inflatable dams and automated sluice gates. These are most often used for in-system storage purposes. Table 4 presents the base construction costs for inflatable dams and automated sluice gates.

Table 4
In-System Storage Facilities Base Construction Costs

Diameter (inches)	Base Construction Cost ($)
Inflatable Dams	
48	554,000
54	585,000
60	618,000
72	689,000
84	971,000
96	1,103,000
Automated Sluice Gates	
32 x 48 up to 60 x 40	232,000

Inflatable dam costs cover a size range for pipe diameter between 48 and 96 inches. Accessibility to the installation is moderate, requiring demolition. The inflatable dam would be installed within existing piping with no additional structure required. An inflatable dam project would most likely not require additional land acquisition, as the dam is within existing piping and the control panel can be placed in the existing right of way owned by the city. As well, traffic disruption and dewatering is assumed to be nominal unless a unique access must be constructed to install the dam, or bypass pumping becomes required due to location. The cost includes local controls with a panel located at ground access and primary power immediately available. Annual O&M costs for these devices are included within the collection system maintenance costs.

Sluice gate costs range for pipe sizes between 32 inches by 48 inches and 60 inches by 40 inches; costs for other sizes should be determined on a site-specific basis. A sluice gate installation is assumed to include a constructed vault around the existing piping, a new motor operated sluice gate, and local control panel for local and remote activation. Sluice gates using special materials are equipped with unique controls that require separate cost consideration. Annual O&M costs for these devices are included within the collection system maintenance costs.

3.2 End-of-Pipe Treatment Devices

End-of-pipe treatment devices are used to provide floatable control. Two types of technologies are considered for the Raw Sewage Overflow Control Program: netting devices and weir mounted overflow screens. Table 5 presents the base construction costs for the end-of-pipe treatment devices.

Table 5
End-of-Pipe Treatment Devices Base Construction Costs

Technology	Base Construction Cost ($/MGD)
Netting devices	500 – 3,000
Overflow screens	500 – 3,000

The typical aperture opening for these facilities is 0.5 inch. Costs may vary depending on flow rates, site constraints, new construction, and screen type and size. This cost includes installation of the netting device on the pipe outfalls, accessible from the stream bank and not requiring any special equipment for installation.

In-line screen installation costs consider utilizing the existing right of way for constructing a vault and screen box around the existing outfall pipe. The concrete vault is assumed to be precast (except for the floor), and costs include excavation and backfill. Pavement restoration depends upon location and is applied using the site adjustment factor.

The annual O&M costs for 10 overflow events per year can be estimated using the following equation:

$$O\&M\ Cost\ (\$thousands) = (current\ ENRCCI/6635) * (0.00012\ Q^2 + 0.071\ Q + 5.34)$$

Where:
Q = *Facility capacity in million gallons per day (MGD)*

For 30 overflow events per year, the equation is as follows:

$$O\&M\ Cost\ (\$thousands) = (current\ ENRCCI/6635) * (0.00048\ Q^2 + 0.098\ Q + 12.64)$$

4.0 Conveyance Facilities

This section presents cost estimating procedures for the following conveyance alternatives:

- Regulator modification
- Static regulators
- Interceptor connections
- Sewer construction

- Pumping facilities
- Total sewer separation
- Partial sewer separation

4.1 Regulator Modification

Regulator modifications include a newly constructed vault or manhole, complete with weir or similar regulating device. The cost of these typical features vary greatly with pipe size, depth and location. Table 6 presents the base construction costs for regulator modifications. Sizes up to 96 inches are identified; the estimator may adjust or expand costs where needed.

Table 6

Regulator Modification Base Construction Costs

Diameter (inches)	Base Construction Cost ($)
Up to 36 inches	30,000
42 to 96 inches	60,000

The estimator must carefully evaluate and adjust these guideline costs to reflect actual conditions and extent of structure anticipated. These costs assume the new vault or manhole is constructed around the existing pipe and no additional piping is included. If additional piping is required, the estimator should add costs based on sewer construction costs. Annual O&M costs for these devices are included within the collection system maintenance costs.

4.2 Static Regulator

Static regulators include a newly constructed vault or manhole, complete with weir or similar regulating device. The cost of these typical features vary greatly with pipe size, depth, and location. Table 7 presents the base construction cost for static regulators. Sizes up to 96 inches are identified; the estimator may adjust or expand costs where needed.

Table 7

Static Regulator Base Construction Costs

Diameter (inches)	Base Construction Cost ($)
Up to 36 inches	250,000
42 to 96 inches	500,000

The estimator must carefully evaluate and adjust these guideline costs to reflect actual conditions and extent of structure anticipated. These costs assume the new vault or manhole is constructed around the existing pipe and no additional piping is included. If sluice gates are used within the new regulator, the costs should be based on those for automated sluice gates, not on regulators. The costs include excavation, sheeting and bracing, disposal, fill, and compaction. Annual O&M costs for these devices are included within the collection system maintenance costs.

4.3 Interceptor Connection

The interceptor connection cost includes the connection to the existing piping, the connection to the interceptor and the new interconnecting piping, not to exceed 500 feet. As part of the assembly, the manhole, at the existing system tie-in, is included in the estimated costs. Excavation and backfill is included. Dewatering and pavement restoration are site-specific and applied using the site adjustment factors. The cost of these typical features vary greatly with pipe size, depth, and location.

Table 8 presents the base construction costs for interceptor connections. Costs are graduated in three sizes. The estimator must carefully evaluate and adjust these guideline costs to reflect actual conditions and extent of structure anticipated. Annual O&M costs for these devices are included within the collection system maintenance costs.

Table 8

Interceptor Connection Base Construction Costs

Diameter (inches)	Base Construction Cost ($)
Up to 36 inches	60,000
42 to 60 inches	120,000
72 to 108 inches	200,000

4.4 Sewer Construction

Tables 9 and 10 present base construction costs for reinforced concrete pipe (RCP) sewer construction and pre-cast concrete box culvert construction, respectively. The pipe is assumed to be RCP Class IV with gaskets and PVC liner for corrosion protection; the box culvert is assumed to be reinforced to C-850. Pipe diameters range from 12 to 120 inches, and the box culvert sizes include an equivalent pipe cross section from 132 to 312 inches.

Table 9

Sewer Construction Costs

Diameter (inches)	Cost ($/linear foot)	Cost($/inch dia./ linear foot)
12	$47	$4
15	$53	$4
18	$61	$3
24	$77	$3
30	$117	$4
36	$151	$4
42	$192	$5
48	$250	$5
60	$272	$5
72	$349	$5
84	$487	$6
96	$975	$10
102	$1,117	$11
108	$1,229	$11
120	$1,467	$12

Table 10

Box Culvert Construction Costs

Equivalent Pipeline Diameter (inches)	Cost ($/lin. foot)	Cost ($/inch eq dia./lin. foot)
132	$2,004	$15
144	$2,120	$15
168	$2,346	$14
192	$2,957	$16
216	$3,443	$16
240	$4,436	$19
264	$5,142	$20
288	$6,741	$24
312	$7,394	$24

The cost includes excavation, sheeting and bracing, bedding, backfill, disposal, compaction, and pipe with an average depth of 16 feet not including rock excavation. Manholes and appurtenances are added by means of the site adjustment factors. Pavement restoration, traffic routing and extensive dewatering are also covered by these adjustment factors. The estimator is responsible for applying these factors to represent anticipated conditions.

For sewers greater than 0.5 miles in length, the following discount is applied:

5 percent for greater than 0.5 miles

10 percent for greater than 2 miles

15 percent for greater than 5 miles

For sewers less than 200 feet in length, an additional 10 percent is added to the pipe cost.

The annual O&M cost can be projected by the following equation:

*Cost ($) = ($76.80) * (2 hours) * (# of events per year) + (0.0025 * Capital Cost)*

4.5 Pumping Facilities

Table 11 presents the base construction costs for pumping facilities. These costs are based on the following equation:

$$\text{Cost (\$M)} = (\text{Current ENRCCI}/6635) * 0.40 * Q^{0.704}$$

Where:

Q = Facility capacity in million gallons per day (MGD)

Table 11

Pumping Facilities Construction Costs

Pumping Capacity (MGD)	Base Construction Cost ($)	Unit Construction Cost ($/gpd)	Annual O&M Cost ($)

Pumping Capacity (MGD)	Base Construction Cost ($)	Unit Construction Cost ($/gpd)	Annual O&M Cost ($)
1	400,000	$0.40	15,000
2	651,000	$0.33	24,000
5	1,240,000	$0.25	44,000
10	2,020,000	$0.20	70,000
15	2,687,000	$0.18	92,000
20	3,291,000	$0.16	111,000
25	3,850,000	$0.15	129,000
30	4,378,000	$0.15	146,000
40	5,360,000	$0.13	177,000
50	6,272,000	$0.13	205,000
60	7,131,000	$0.12	232,000
70	7,948,000	$0.11	257,000
80	8,732,000	$0.11	281,000
90	9,487,000	$0.11	304,000
100	10,217,000	$0.10	326,000
120	11,616,000	$0.10	368,000
140	12,948,000	$0.09	408,000
160	14,224,000	$0.09	447,000
180	15,453,000	$0.09	483,000
200	16,643,000	$0.08	518,000

The cost estimates for wastewater pumping assume the following:

- Fully enclosed, submersible type structure, concrete construction
- Excavation and backfill included
- One redundant pump
- Aboveground control panel and SCADA for reporting failures
- Immediately available primary power
- Pumping equipment capable of meeting the peak flow with largest unit out of service.
- No force main; use pipeline costs as needed.
- No sewer work to route flow to the pump station; use sewer construction if required.

These assumptions and base construction costs apply only to traditional, low head sanitary sewer collection system pump stations. High head and high flow pump stations, such as tunnel dewatering, must be independently estimated.

Annual O&M costs estimated for pumping facilities can be projected by the following equation:

$$\textit{Cost (\$Thousands)} = (\textit{Current ENRCCI}/6635) * 14.95 * Q^{0.669}$$

Where:

Q = facility capacity in MGD

4.6 Total Sewer Separation

Table 12 presents the base construction cost for total sewer separation for differing land types. The cost includes excavation, sheeting and bracing, backfill, disposal, compaction, and sewer construction. Manholes, utility conflicts, dewatering, traffic routing, pavement restoration and excess materials disposal are applied by means of the site adjustment factor.

Table 12

Total Sewer Separation Construction Costs

Land Type	Base Construction Cost ($/acre)
Rural	75,000
Suburban	92,000
Urban	100,000

Annual O&M costs for sewer separation can be projected by the following equation:

*Cost ($) = (0.0025 * Capital Cost)*

5.0 Treatment Facilities

Construction cost relationships are used for treatment and storage facilities. Costs for these facilities reflect the basic structure and ancillary equipment such as grates, valves and conduits. These costs do not include pumping. Each treatment process is individually identified for singular use, as in the case of enhanced high rate treatment.

5.1 Mechanical Screens

Table 13 presents the base construction costs for mechanical screens. These costs are based on the equation below.

$$Cost\ (\$M) = (current\ ENRCCI/6635) * 0.099\ Q^{0.843}$$

Where:

Q = facility capacity in MGD

The annual O&M costs for 10 overflow events per year can be estimated using the following equation:

$$Cost\ (\$thousands) = (current\ ENRCCI/6635) * (0.00012\ Q^2 + 0.071\ Q + 5.34)$$

The annual O&M costs for 30 overflow events per year can be estimated using the following equation:

$$Cost\ (\$thousands) = (current\ ENRCCI/6635) * (0.00048\ Q2 + 0.098\ Q + 12.64)$$

Table 13

Mechanical Screens Construction Costs

Screen Capacity (MGD)	Construction Cost ($)	Unit Construction Cost ($/gpd)	Annual O&M Cost ($)	
			10 Overflow events/year	30 Overflow events/year
0.8	62,000	$0.08	6,000	13,000
1	75,000	$0.08	6,000	13,000

Screen Capacity (MGD)	Construction Cost ($)	Unit Construction Cost ($/gpd)	Annual O&M Cost ($)	
			10 Overflow events/year	30 Overflow events/year
2	134,000	$0.07	6,000	13,000
5	290,000	$0.06	6,000	14,000
10	519,000	$0.05	7,000	14,000
15	730,000	$0.05	7,000	15,000
20	930,000	$0.05	7,000	15,000
30	1, 310,000	$0.04	8,000	17,000
40	1,670,000	$0.04	9,000	18,000
50	2,015,000	$0.04	10,000	19,000
60	2,350,000	$0.04	11,000	21,000
70	2,675,000	$0.04	11,000	22,000
80	3,000,000	$0.04	12,000	24,000
90	3,300,000	$0.04	13,000	26,000
100	3,600,000	$0.04	14,000	28,000
120	4,200,000	$0.04	16,000	32,000
140	4,800,000	$0.03	18,000	36,000
160	5,370,000	$0.03	20,000	41,000
180	5,950,000	$0.03	23,000	46,000
200	6,480,000	$0.03	25,000	52,000

The cost equation applies to facility sizes in the range of 0.8 and 200 MGD. Beyond 200 MGD, the applications are modular and multiples of smaller sizes. With multiples of a selected size, there is little economy of scale; therefore, the costs can be represented by multiplying the cost for a single unit. The cost shown includes a motorized screen equipment, power supply, controls, and structure to support screens. No building enclosure is envisioned, and no odor control facilities are included. Structure construction costs include excavation, backfill and concrete.

The costs proposed in this segment do not include the housing or containment of these screens. If these screens are intended (in a particular option) to be installed as primary screens for influent wastewater, a permanent enclosure and odor control should be added to the anticipated costs. These can be added by an independent estimate. Site adjustment factors add costs for issues such as dewatering, spoil disposal and appurtenances.

5.2 Chlorination Disinfection and Dechlorination

This section discusses gas chlorine and liquid chlorine disinfection.

- **Gas Chlorination and Dechlorination**. Table 14 presents the base construction costs for gas chlorination and sulphur dioxide dechlorination, which is based on the cost equation below.

$$\text{Cost (\$M)} = (\text{current ENRCCI}/6635) * (0.0443\ Q^{0.655} + 0.0655\ Q^{0.417})$$

Where:
Q = Facility capacity in MGD

The annual O&M costs can be estimated using the following equation.

*Cost ($Thousands) = (current ENRCCI/6635) * 12.531 Q0.614*

Table 14
Gas Chlorination/Disinfection and Dechlorination Construction Costs

Facility Capacity (MGD)	Construction Cost ($)	Unit Construction Cost ($/gpd)	Annual O&M Cost ($)
1	110,000	$0.11	13,000
2	158,000	$0.08	20,000
5	256,000	$0.05	34,000
10	372,000	$0.04	52,000
15	464,000	$0.03	67,000
20	544,000	$0.03	79,000
30	682,000	$0.02	102,000
40	802,000	$0.02	121,000
50	910,000	$0.02	139,000
60	1,009,000	$0.02	155,000
70	1,102,000	$0.02	171,000
80	1,189,000	$0.01	185,000
90	1,272,000	$0.01	199,000
100	1,352,000	$0.01	212,000
120	1,502,000	$0.013	237,000
140	1,642,000	$0.012	261,000
160	1,775,000	$0.011	283,000
180	1,901,000	$0.011	304,000
200	2,021,000	$0.010	325,000
500	3,470,000	$0.007	570,000
1000	5,255,000	$0.005	871,000
2000	7,995,000	$0.004	1,333,000

The cost includes the chemical storage tanks, chlorine evaporators and chlorinators, chemical feed pumps, reaction tank and mixer and instrumentation. The cost does not include a chemical building or chlorine scrubber. For facilities larger than 2,000 MGD, a multiple unit approach should be used.

- **Liquid Chlorination and Dechlorination**. Table 15 presents the base construction costs for liquid chlorination using sodium hypochlorite and sodium bisulfite dechlorination. These costs are based on the cost equation below.

$$Cost\ (\$M) = (current\ ENRCCI/6635) * 0.178\ Q^{0.464}$$

Where:

Q = Facility capacity in MGD

The annual O&M costs can be estimated using the following equation.

$$Cost\ (\$M) = (current\ ENRCCI/6635) * 12.531\ Q^{0.614}$$

Table 15
Liquid Chlorination and Dechlorination Construction Costs

Facility Capacity (MGD)	Construction Cost ($)	Unit Construction Cost ($/gpd)	Annual O&M Cost ($)
1	178,000	$0.18	13,000
2	246,000	$0.12	20,000
5	376,000	$0.08	34,000
10	518,000	$0.05	52,000
15	625,000	$0.04	67,000
20	715,000	$0.04	79,000
30	862,000	$0.03	102,000
40	986,000	$0.02	121,000
50	1,093,000	$0.02	139,000
60	1,189,000	$0.02	155,000
70	1,278,000	$0.02	171,000
80	1,359,000	$0.02	185,000
90	1,436,000	$0.02	199,000
100	1,507,000	$0.02	212,000
120	1,640,000	$0.014	237,000
140	1,762,000	$0.013	261,000
160	1,875,000	$0.012	283,000
180	1,980,000	$0.011	304,000
200	2,079,000	$0.010	325,000
500	3,180,000	$0.006	570,000
1000	4,387,000	$0.004	871,000
2000	6,051,000	$0.003	1,333,000

The cost equation above applies to facility sizes in the range of 1 and 2,000 MGD. The base costs do not include a building or enclosure to house the system. It is assumed that the equipment will be housed in a multi-use facility with other like equipment. If a structure is desired, the estimator shall include costs reflecting the addition.

Gas chlorination may be used when facilities are located at the advanced wastewater treatment plants. For remote locations, sodium hypochlorite is the preferred disinfectant.

5.3 Ultraviolet Disinfection

Table 16 presents the base construction costs for UV disinfection facilities. These costs are based on the cost equation below.

$$Cost\ (\$) = (current\ ENRCCI/6635) * (418{,}701 + 55817 * Q)$$

Where:

Q = Facility capacity in MGD

The annual O&M costs can be estimated using the following equation.

*Cost ($) = (current ENRCCI/6635) * 5475 * Q*

Where:

Q = Facility capacity in MGD

Table 16
Ultraviolet Disinfection Construction Costs

Facility Capacity (MGD)	Construction Cost ($)	Unit Construction Cost ($/gpd)	Annual O&M Cost ($)
1	475,000	$0.48	6,000
2	531,000	$0.27	11,000
5	698,000	$0.14	28,000
10	977,000	$0.10	55,000
15	1,256,000	$0.08	83,000
20	1,536,000	$0.08	110,000
30	2,094,000	$0.07	165,000
40	2,652,000	$0.07	220,000
50	3,210,000	$0.06	274,000
60	3,768,000	$0.06	329,000
70	4,326,000	$0.06	384,000
80	4,885,000	$0.06	439,000
90	5,443,000	$0.06	493,000
100	6,001,000	$0.06	548,000
120	7,117,000	$0.06	658,000
140	8,234,000	$0.06	767,000
160	9,350,000	$0.06	877,000
180	10,466,000	$0.06	986,000
200	11,583,000	$0.06	1,096,000

The UV disinfection facility consists of two parts: the outdoor channel with submerged tubes and ready access for maintenance, and an enclosure that houses the electronics and power panels, complete with HVAC. Transmittance is assumed at 45 percent to achieve a 3 log fecal coliform reduction. Assumptions include readily available 480-volt power and process instrumentation. Beyond 200 MGD, multiple units of smaller sizes should be used.

5.4 Enhanced High Rate Clarification

Table 17 presents the base construction costs for enhanced high rate clarification facilities. These costs are based on the cost equation below.

*Cost ($M) = (current ENRCCI/6635) * (646,079 + 130114 * Q)*

Where:

Q = Facility capacity in MGD

The annual O&M costs can be estimated using the following equation.

*Cost ($Thousands) = (current ENRCCI/6635) * 18.238 * Q0.592*

Where:

Q = Facility capacity in MGD

The costs reflect known equipment and installation costs for ballasted flocculation equipment packages. For comparison, an assumed loading rate of 60 GPM/SF may be used. Loading rate is at peak hourly flow, applied to the area of clarification only. It was assumed that the vendor equipment would be delivered, assembled and installed on a concrete pad above grade. Primary power was assumed to be immediately available and piping modifications were nominal. Pumping or pump station costs were not included and would be applied by using pump station costs. Force main and outfall lines were excluded and would be added using unit costs provided elsewhere. Site specific costs, such as traffic reroute, or paving repair is applied by adjustment factor.

Table 17
Enhanced High Rate Clarification Construction Costs

Facility Capacity (MGD)	Construction Cost ($)	Unit Construction Cost ($/gpd)	Annual O&M Cost ($)
1	777,000	$0.78	19,000
2	907,000	$0.45	28,000
5	1,297,000	$0.26	48,000
10	1,948,000	$0.19	72,000
15	2,598,000	$0.17	91,000
20	3,249,000	$0.16	108,000
30	4,550,000	$0.15	137,000
40	5,851,000	$0.15	162,000
50	7,152,000	$0.14	185,000
60	8,453,000	$0.14	206,000
70	9,755,000	$0.14	226,000
80	11,056,000	$0.14	245,000
90	12,357,000	$0.14	262,000
100	13,658,000	$0.14	279,000
120	16,260,000	$0.14	311,000
140	18,863,000	$0.13	341,000
160	21,465,000	$0.13	368,000
180	24,067,000	$0.13	395,000
200	26,669,000	$0.13	420,000
220	29,272,000	$0.13	445,000
240	31,874,000	$0.13	468,000
260	34,476,000	$0.13	491,000
280	37,078,000	$0.13	513,000
300	39,681,000	$0.13	534,000
320	42,283,000	$0.13	555,000
340	44,885,000	$0.13	575,000
360	47,488,000	$0.13	595,000
380	50,090,000	$0.13	615,000
400	52,692,000	$0.13	634,000
420	55,294,000	$0.13	652,000

Facility Capacity (MGD)	Construction Cost ($)	Unit Construction Cost ($/gpd)	Annual O&M Cost ($)
440	57,897,000	$0.13	670,000
460	60,499,000	$0.13	688,000
480	63,101,000	$0.13	706,000
500	65,704,000	$0.13	723,000

6.0 Storage Facilities

Two types of storage facilities are considered for the Raw Sewage Overflow Control Program: subsurface storage and deep tunnels. This section briefly describes these facilities and provides estimated base construction costs.

6.1 Subsurface Storage

Table 18 presents the base construction costs for subsurface storage. These costs are based on the cost equation below.

*Cost ($M) = (current ENRCCI/6635) * 5.026 V0.826*

Where:

V = Facility volume in million gallons (MG)

Annual O&M costs can be estimated using the following equation:

*Cost ($) = ($76.80) * (2 hours) * (# of events per year) + (0.0025 * Capital Cost)*

These costs apply for facility sizes in the range of 0.15 and 30 MG. Beyond 30 MG, multiple storage cells would be expected, and these costs represent those of an individual cell.

The earthen basin is assumed to be installed below grade and open to the atmosphere. The costs for the earthen basin include excavation, synthetic liner and associated piping. Neither mechanized cleaning systems nor pump stations are included. An equation adjustment factor of 0.15 will be applied to better reflect local construction costs.

Table 18
Earthen Basin Subsurface Storage Construction Costs

Storage Volume (MG)	Construction Cost ($)	Unit Construction Cost ($/gallon)
0.15	158,000	$1.05
0.3	279,000	$0.93
0.5	425,000	$0.85
0.8	627,000	$0.78
1	754,000	$0.75
3	1,868,000	$0.62
5	2,849,000	$0.57
8	4,200,000	$0.53
10	5,050,000	$0.51
15	7,060,000	$0.47
20	8,954,000	$0.45
25	10,766,000	$0.43
30	12,516,000	$0.42

For prestressed concrete tank storage, costs include an at-grade tank with roof. No pumping, valving or cleaning equipment is included. An equation adjustment factor of 0.34 will be applied to better reflect local construction costs.

Table 19
Prestressed Concrete Tank Subsurface Storage Construction Costs

Storage Volume (MG)	Construction Cost ($)	Unit Construction Cost ($/gallon)
0.15	357,000	$2.38
0.3	632,000	$2.11
0.5	964,000	$1.93
0.8	1,422,000	$1.78
1	1,709,000	$1.71
3	4,235,000	$1.41
5	6,458,000	$1.29
8	9,521,000	$1.19
10	11,448,000	$1.14
15	16,002,000	$1.07
20	20,295,000	$1.01
25	24,402,000	$0.98
30	28,369,000	$0.95

Cast-in-place tanks were assumed to be installed below grade with a covered top, including excavation, backfill and disposal of excess. Baffling was not required but represents a nominal increase (when applied for a chlorine contact chamber). Excavation dewatering is not included; property requirements are applied as an additional cost after construction. If pump station costs or disinfection facilities are desired at one of these sites, the costs for these technologies in other equations may be added. An equation adjustment factor of 0.50 will be applied to better reflect local construction costs.

Table 20
Cast-in-Place Tank Subsurface Storage Construction Costs

Storage Volume (MG)	Construction Cost ($)	Unit Construction Cost ($/gallon)
0.15	525,000	$3.50
0.3	930,000	$3.10
0.5	1,418,000	$2.84
0.8	2,091,000	$2.61
1	2,514,000	$2.51
3	6,228,000	$2.08
5	9,497,000	$1.90
8	14,002,000	$1.75
10	16,836,000	$1.68
15	23,533,000	$1.57
20	29,846,000	$1.49
25	35,886,000	$1.44
30	41,719,000	$1.39

6.2 Deep Tunnels

Table 21 presents the base construction costs for deep tunnels. These costs are based on the cost equation below.

*Cost ($ per LF) = (current ENRCCI/6635) * (1450 + 145 D)*

Where:

D = Inside tunnel diameter

Annual O&M costs for deep tunnels can be projected by the following equation:

*Cost ($) = ($76.80) * (2 hours) * (# of events per year) + (0.0025 * Capital Cost)*

Table 21
Deep Tunnel Construction Costs

Inside Diameter (feet)	Cost per Linear Foot ($)
5	2,175
10	2,900
15	3,625
20	4,350
25	5,075
30	5,800
35	6,525

The costs include mobilization, tunnel shafts, dewatering, material disposal and tunnel lining. Costs represent a complete tunnel in place, without any ancillary features such as deep pump stations or odor control facilities. These shall be added by the estimator, if needed. Costs not included in the base, but that may apply based upon site-specific considerations, include excess dewatering, utility relocation, boulder zone and pavement restoration.

Tunnel costs assume tunneling in good rock, limited groundwater, no grouting, no ground gasses and an open faced tunnel boring machine. While the rock conditions in Indianapolis have not yet been sufficiently defined, initial assessments indicate geology at the intended tunneling depth to be sedimentary dolomite, limestone and shale formations.